Endovascular Thermal Coagulation Using the Double-Helix GDC

Feasibility Study in Experimental Aneurysms

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Summary

An experimental study was undertaken to explore the possibility of treating this subset of aneurysms with thermal coagulation.

Endovascular endosaccular thermal coagulation of experimental aneurysms was successfully performed using a radiofrequency electrical current applied to a novel device, the double-helix GDC. Theoretically this technique could be utilized in selected patients to occlude large and giant intracranial aneurysms.

Introduction

Currently, complete endovascular endosaccular occlusion of large and giant wide-necked aneurysms constitutes a significant challenge. An experimental study was undertaken to explore the possibility of treating this subset of aneurysms with thermal coagulation.

This paper reports on the thermal endovascular occlusion of large and giant wide-necked experimental aneurysms using a novel device, the Double-Helix GDC.

Material and Methods

The Double-Helix GDC (manufactured as prototypes by Target Therapeutics-Boston Scientific Neurovascular, Fremont, CA) is a long, soft platinum coil with two stainless steel delivery wires. The delivery wires have electrolytically detachable junctions. The coil is 20 cm long and has a diameter of 0.021 inches. The double-helix platinum coil is Teflon laminated and, therefore, electrically insulated from the external environment. Its construction involves intertwining two GDC coils in such a way that the device resembles the convolutions and shape of DNA. With regards to its modus operandi, the Double-Helix GDC may be compared with the electric resistance of a boiler or of a coffee machine. A radiofrequency current is applied to the two proximal ends of the delivery wires to heat the whole platinum coil. Bench testings were performed to assess the power of the radiofrequency energy necessary to obtain a given coil temperature.

The coil can be introduced into an aneurysm via a microcatheter. A balloon is then positioned across the neck of the aneurysm in the parent artery and inflated. This balloon blocks the blood flow, while the blood within the aneurysm is heated by the Double-Helix GDC. The Double-Helix GDC is then detached by electrolysis within the coagulated aneurysm. More than one coil can be delivered and detached into an aneurysm, if necessary. The microcatheter is then removed.

Five acute experimental studies were performed in five swine at the Leo G. Rigler Research Center, Division of Interventional Neuroradiology, University of California at Los Angeles. Under general anesthesia, large and giant wide-necked saccular aneurysms were surgically created on the common carotid artery of each swine. The operative field was intentionally left open and exposed to measure the temperature of the aneurysm and surrounding tissues with

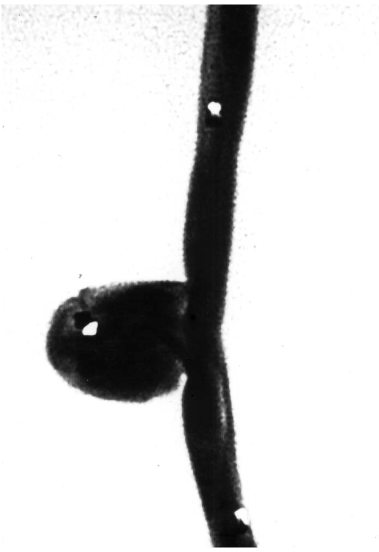

Figure 1 Common carotid artery angiogram depicting a large, wide-necked experimental aneurysm. The tip of a microcatheter is within the aneurysm sac. The two markers of an inflatable balloon are visible in the parent artery, across the aneurysm neck.

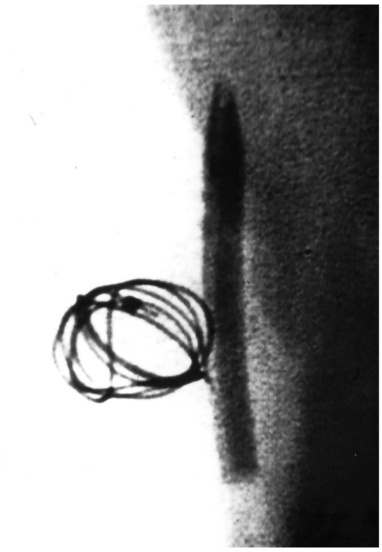

Figure 2 The balloon is inflated while the intra-aneurysmal coil is heated with radiofrequency. Only one double-helix GDC was utilized (see also text).

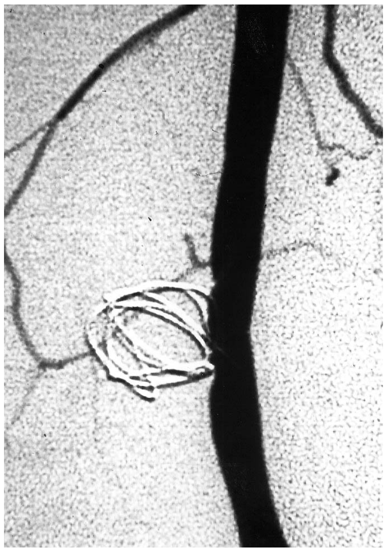

Figure 3 Post heating angiogram showing complete occlusion-coagulation of the aneurysm with preservation of the parent artery.

the aid of a thermal camera. After surgery, two introducers were positioned in the femoral arteries, under systemic heparinization. Angiograms depicted the dimensions and shape of the aneurysm. An angioplasty balloon was advanced and positioned across the neck of the aneurysm in the parent vessel (figure 1). A Tracker-25 microcatheter was then advanced and positioned in the aneurysmal sac (figure 1). Through the microcatheter, a Double-Helix GDC was delivered into the aneurysm. The balloon was then inflated to block the flow in the aneurysm (and in the parent vessel) (figure 2). Subsequently, a radiofrequency current was ap-

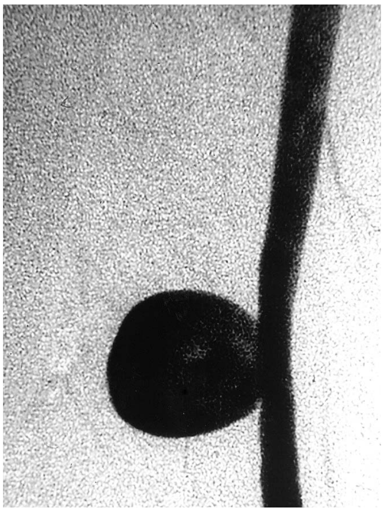

Figure 4 Common carotid artery angiogram showing a giant, wide-necked experimental aneurysm, before treatment.

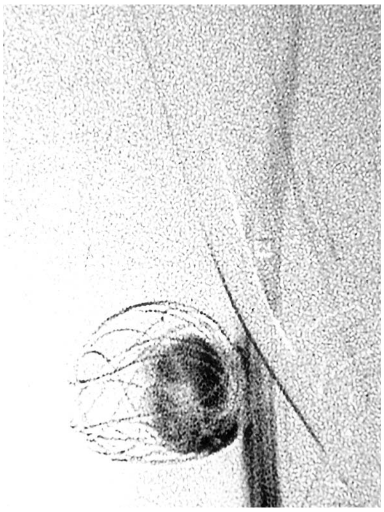

Figure 5 Angiogram showing the gradual, overtime progression of aneurysm coagulation, due to the heating of the intra-aneurysmal coil.

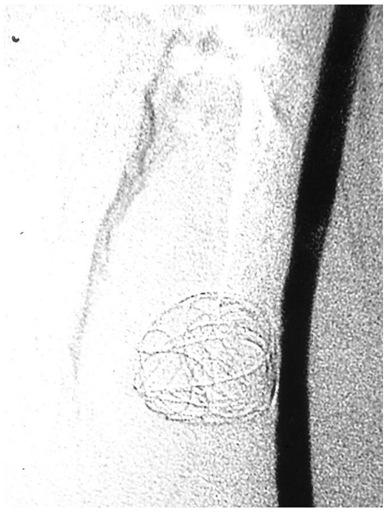

Figure 6 After deposition and heating of a second coil the aneurysm is completely occluded, with preservation of the parent vessel.

plied to the proximal end of the two delivery wires for 15 minutes.

The magnitude of the radiofrequency was set to a value that would heat the coil to 70° centigrade. On average, two Double-Helix GDCs were delivered and deposited in each aneurysm, and electrolytically detached. The aneurysm packing density was loose. At the end of the procedure the delivery wires, balloon and Tracker microcatheter were withdrawn. During the delivery of the radiofrequency (i.e. during the heating of the aneurysm), a thermal camera positioned over the exposed aneurysm measured the temperature in the aneurysm and in the surrounding tissues. This allowed the correlation of the temperature level with the degree of occlusion. The animals were then sacrificed.

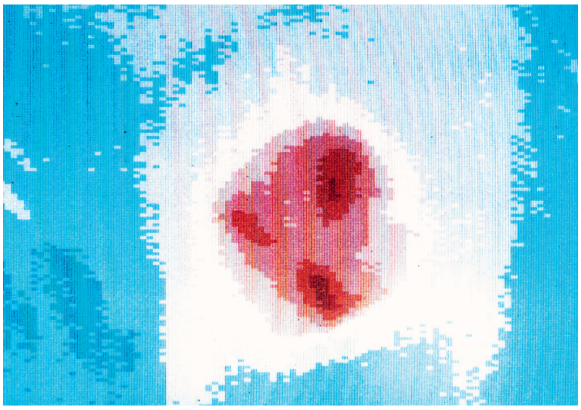

Figure 7 A thermal camera, positioned over an experimental aneurysm, monitored the progressive increase of the temperature. This figure shows that the heating of the aneurysm had just started. Light blue = 37-39°C; Pink = 43-45°C; Purple = 49-51°C; Red = 55-57°C; Yellow = 64-66°C; White = 70-72°C.

Results

Endovascular heating and occlusion of experimental aneurysms with the Double-Helix GDC was possible in all animals (figure 1-6).

Thrombosis of the aneurysms progressed over time (figure 5) until complete occlusion was achieved (figure 6). These results were obtained in spite of a loose coil packing of the aneurysm (figures 3 and 6).

The delivery of the Double-Helix GDC coils through the microcatheter was almost as smooth as the delivery of standard GDCs.

It was always possible to electrolytically detach the coils and to uneventfully withdraw the delivery wires, microcatheter, and occlusion balloon. No apparent blood clots were noted outside the aneurysmal neck.

The thermal camera detected the progressive temperature increase in the aneurysm, its distribution in the periphery of the aneurysm and in the surrounding tissues (figure 7,8,9). The rate of aneurysm occlusion was proportional to the temperature of the coil (figure 5). Only a moderate amount of heat appeared to leave the aneurysmal wall, toward the surrounding tissues (figure 7,8,9).

Discussion

Historical overview

Intra-aneurysmal blood heating via the extravascular approach was utilized in the first half of the last century to produce thrombosis and occlusion of inoperable aneurysms. In 1938 Blakemore and King [1] introduced ten meters of a silver-copper alloy into aneurysms of the aorta and heated the wire to 80°C using an electric current. In 1941 Werner, Blakemore and King [3] reported successful electrothermic thrombosis of an intracranial aneurysm. They utilized nine meters of silver wire and applied an electric current to the wire to heat the aneurysm to 80°C. In 1987 Yamanashi and colleagues [4] utilized an electromagnetic field-focusing probe to heat experimental abdominal aneurysms of the aorta. The aneurysms were placed under a solenoidal radiofrequency coil while the tip of a field-focusing probe was inserted in the aneurysm. They observed thrombosis and shrinkage of the

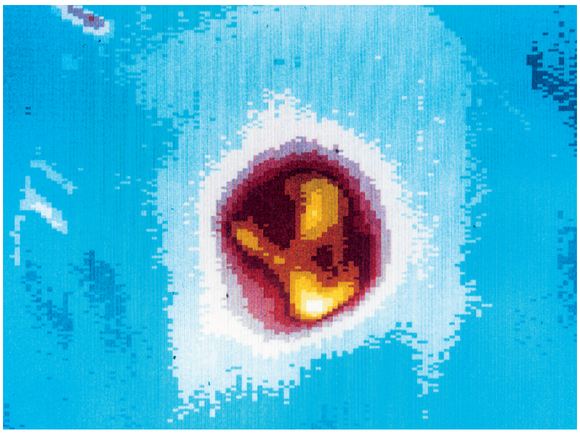

Figure 8 Figure showing the aneurysm temperature after seven minutes of heating: the temperature increased all over the aneurysm, in an irregular fashion. Light blue = 37-39°C; Pink = 43-45°C; Purple = 49-51°C; Red = 55-57°C; Yellow = 64-66°C; White = 70-72°C.

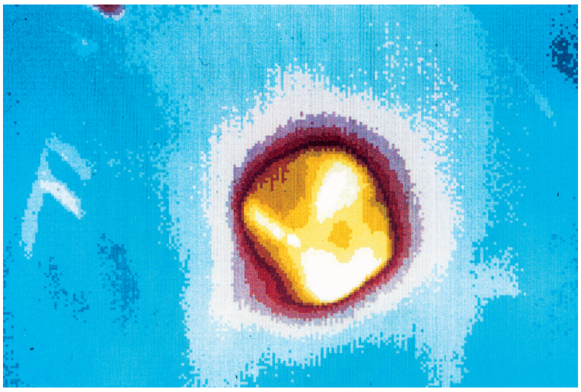

Figure 9 Figure showing the aneurysm temperature at the end of the procedure, after 15 minutes of heating. The aneurysm temperature reaches 70°C, in an almost uniform fashion. Light blue = 37-39°C; Pink = 43-45°C; Purple = 49-51°C; Red = 55-57°C; Yellow = 64-66°C; White = 70-72°C.

aneurysms. Other researchers attempted the occlusion of experimental aneurysms with laser-induced heat via the endovascular approach [2]. Neither the extravascular, nor the endovascular methods obtained much success.

Large and giant wide-necked intracranial aneurysms are difficult to treat by any means. Currently, the endovascular treatment of these lesions can be performed by replacing the intra-aneurysmal blood with either coils or glues. Both kinds of treatment present disadvantages. In this subset of aneurysms, coil occlusion is often subtotal; it is also often plagued with the phenomenon of coil compaction in the months that follow the procedure. Glue injection is difficult to perform and can be complicated by ischemic phenomena in the distal vasculature.

Thermal coagulation

The technique of thermal blood coagulation allowed the occlusion of experimental large and giant wide-necked saccular aneurysms by changing the chemical and physical structure of the intra-aneurysmal blood. Thermal coagulation of blood is due to protein denaturation. The increase in temperature leads to a non-specific aggregation of polypeptide chains, which provoke protein denaturation. The protein melting point is defined as the temperature at which the protein denatures. Coagulation is the random aggregation of already denatured protein molecules. The formation of the coagulum is usually thermally irreversible. At 71°C or higher, the physical characteristic of the solution that contains proteins changes, due to the presence of denaturated aggregates: from a liquid colloidal status, the solution turns into a semi-solid (gel) status. It is like heating egg whites.

Drawbacks

One potential drawback of this technique is that the heat could leave the aneurysmal wall, reaching the surrounding tissues. The wall of the aneurysm, however, could act as a barrier that lessens the amount of heat propagation away from the aneurysm. The measurements with the thermal camera in this study showed that the heat that leaves the aneurysm is in the temperature range of 40° to 42° C.

Another potential drawback is that clots or portions of the intra-aneurysmal gel may become dislodged while withdrawing the microcatheter from the aneurysm. This however, did not occur in the present experimental study.

Another possible drawback is that 15 minutes of occlusion of the aneurysm parent vessel are necessary to induce the increase in temperature and confine it in the aneurysm. This length of occlusion may not always be tolerated in the clinical setting.

Conclusions

Endovascular endosaccular thermal coagulation of experimental aneurysms was successfully performed using a radiofrequency electrical current applied to a novel device, the double-helix GDC. Theoretically this technique could be utilized in selected patients to occlude large and giant intracranial aneurysms.

References

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